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# CLIMATE CHANGE ANALYSIS FROM THE PERSPECTIVE OF THE FRACTAL MODEL IN CHINGAZA NATIONAL NATURAL PARK, COLOMBIA

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**ABSTRACT**

Climate change exhibits a complex, non-linear behavior that is characteristic of fractal model theory. Analyzing climate dynamics in the Chingaza National Natural Park according to this context presents a different and complementary approach to the methodologies used in the country to date. Taking into account the fragility, sensitivity and vulnerability of the paramo, a strategic ecosystem of nascent evolution, important in the production and regulation of water, with ample biosphere richness, and with a high level of biodiversity and cultural richness, the information obtained is relevant in the elaboration of mitigation and adaptation strategies to climate change, in making the right decisions in order to prevent the extinction of the paramo, to prevent the extinction of ecosystems, maintain the environmental supply and ecosystem services. For this purpose, climate trends were studied, and models based on fractal geometry were used to analyze the time series of the climatic variables of precipitation and temperature in the Natural Park. This research enriches the current knowledge on climate change in Colombia's natural protected areas to safeguard the natural functions and integrating elements of these areas, which are fundamental in the conservation and preservation of ecosystems.

**Keywords:** climate change - fractal models - national natural parks - conservation areas - high andean ecosystems.

## 1. INTRODUCTION

The Chingaza National Natural Park is a conservation area near the city of Bogotá D.C. considered a strategic ecosystem because of its importance for the country's economy; it is a great source of research is a great source of possibilities for research, education, tourism, and conservation and management experiences and initiatives [1]. Conservation and management experiences and initiatives, it is considered one of the most important and strategic and strategic areas of the National Natural Park System because of the role it plays in the provision of water supply through the Chingaza System, (the largest water concession in the country, operated by the company operated by the company aqueduct and sewer the Bogotá), which benefits close to 10 million people in the Bogotá.

The Bogotá Capital District and surrounding municipalities; the conservation of paramo and Andean Forest ecosystems, essential for the Andean forest, which are fundamental for the regulation of the water cycle in the Orinoco macro-basin; conservation of endemic species of flora and fauna and nationally and globally threatened species; and the and globally threatened species; and the safeguarding of landscapes and sites of high cultural value of the indigenous communities that inhabited communities that inhabited Cundinamarca and Meta, for the inhabitants of the park's zone of influence, who since colonial times have the park's area of influence who have built close relationships with this territory since colonial times, and for the country's historical memory [2].

The essence of this article is to provide tools for the analysis of climate behavior to protect ecosystem services (supply, regulation, support or base and cultural), safeguard the habitat and cultural), safeguard the habitat of fauna and flora species, protect water sources and preserve the evolution of the natural system, as well as to know the evolution of the natural system.

Preserving the evolution of the natural system and gaining a different perspective on climate trends and evolution to and evolution of the climate to make the right decisions for mitigating and adapting to climate change, conserve and adaptation to climate change, preserve the environmental services, functionality, integrity, diversity and health of the ecosystem.

Analyzing climatic phenomena on a regional scale or even on smaller areas (larger scales) ensures reliability of the results due to the sufficient spatial resolution of the models, which means that which implies no distortion of the lines and no smoothing of the heights of orographic features, and the non-use of physical parameterizations not adapted to meso-scale processes. Meso-scale processes.

The analysis of existing correlations and the inference of the values of local climatic parameters between the series of observations between the series of surface climatic observations and the characteristics of this surface (vegetation cover, height, height, height, height, height, height, height, height, height, height, height, height). Characteristics (vegetation cover, altitude, orientation) is achieved by regression and other statistical techniques which statistical techniques which allow to identify notable changes in the climatic potentialities and to draw the climatic potentialities and draw the reality (equilibrium-imbalance) in all its aspects.

## 2. BACKGROUND

Climate change is the variation in the state of the climate, identifiable, for example, by statistical evidence,

in the variations of the mean value or in the variability of its properties that persists over long periods of time, usually decades or longer.

Climate change may be due to natural internal processes or to external forcing's such as modulations of solar cycles, volcanic eruptions, or persistent anthropogenic changes in the composition of the atmosphere due to increased concentrations of greenhouse gases or land use. Greenhouse gas concentrations or land use. Climate change could modify the characteristics of meteorological and hydroclimatic extreme meteorological and hydroclimatic phenomena in their average frequency and intensity will be gradually expressed in their spatial behavior and annual cycle [3].

Climate change is defined as the change in climate attributed directly or indirectly to human activity, in addition to climate variability observed in comparable periods. Climate has variability at all scales of time and space and will always be changing. The interactions of the climate system (atmosphere, ocean, land surface processes, cryosphere, biosphere, and biosphere) occur mainly in the atmosphere and biosphere) occur mainly at the physical interfaces, and to understand these conditions it is necessary to know how they vary within each to know how they vary within each system (Figure-1) [4].

Climate variability refers to the variation of climate on different time and space scales.

Since ancient times, climate fluctuations have occurred on different time scales, caused by processes in the different components of the climate system and by changes in the forcing radiative factors and by changes in the radiative forcing factors. The values of climatological variables (air temperature, precipitation) fluctuate above or below normal, which generally represents the average value of a climate variable, generally represents the average value of a climatological variable over a period of at least 30 years. the sequence of these oscillations around the normal values is known as climatic variability and is the sequence of these oscillations around the normal values is known as climatic variability and its valuation is achieved by determining the difference between the value of the climatological variable and its average value, called anomaly[5].

Adaptation to climate change is the process of adjusting to the present and expected effects of climate change. In social decision-making spheres, it corresponds to the adjustment process that seeks to mitigate the harmful effects and/or take advantage of the present or expected beneficial opportunities of climate and its effects. Expected effects of climate and its effects. In socio-ecosystems, the process of biodiversity adjustment to the current climate and its effects can be to the current climate and its effects can be intervened by society to facilitate adjustment to the expected climate [3].

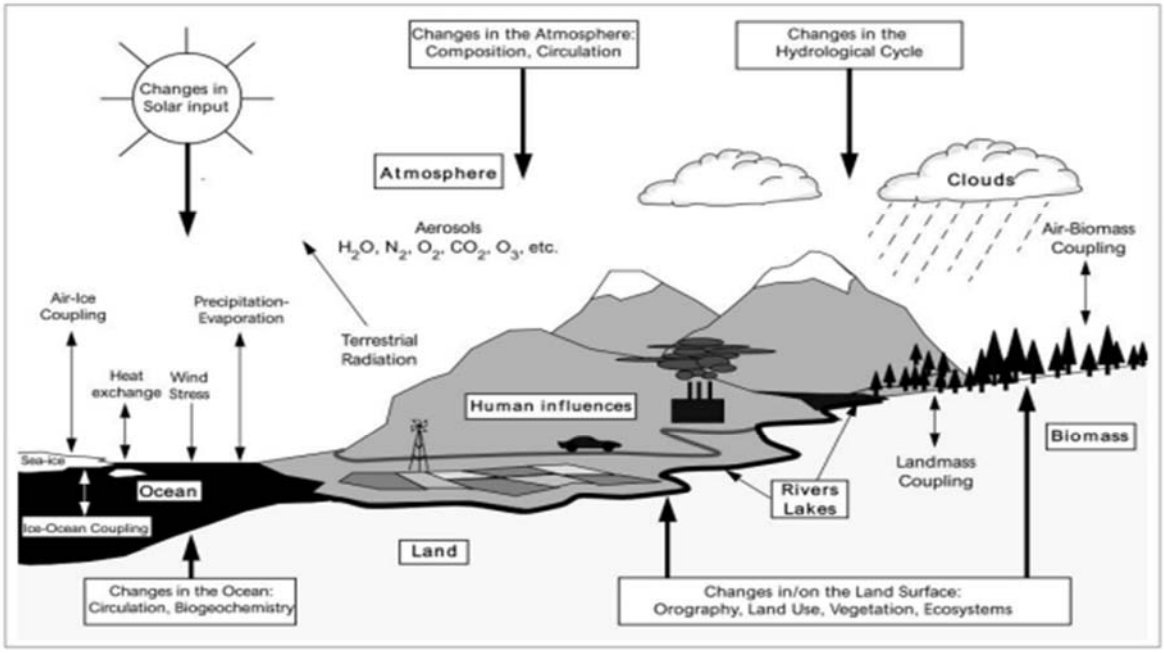


**Figure-1.** Schematic list of the components of the global climate system, their processes and interactions and some aspects that may change [4].

On the other hand, a Protected Area is a delimited geographic space that has been designated, regulated and managed for the achievement of a conservation objective [3]. According to IUCN [6], a Protected Area is a geographic space that is clearly recognized, dedicated and managed, through legal or other effective means, to achieve long-term conservation, effective means to achieve the long-term conservation of nature and its ecosystem services and cultural values. Services and their associated cultural values.

Protected areas are essential for biodiversity conservation. They are the cornerstone of virtually all national and international conservation strategies. They are intended to maintain functioning natural ecosystems, act as refuges for species, and maintain ecological processes unable to survive. Ecological processes unable to survive in terrestrial and marine environments with a higher level of intervention. a higher level of intervention.

Protected areas act as indicators that allow us to understand human interactions with the natural world. They are often the one hope for preventing the extinction of many endangered or endemic species [6].

National Natural Park protected areas (Category II) are large natural or near-natural areas established to protect established to protect large-scale ecological processes, along with the complement of characteristic species and ecosystems [6]. complement of species and ecosystems characteristic of the area, which also provide the basis for spiritual, scientific, cultural, cultural for spiritual, scientific, educational, recreational, and visitor opportunities that are environmentally and culturally compatible [6].

Another important element is climate change in high mountain ecosystems, the effects of climate change on high Andean ecosystems (high andean forest and paramo) are still unpredictable. Several studies mention that the most notorious effects will occur on the water balance and carbon storage, mainly in the paramo. An increase in temperature can release the carbon stored in the soils, and the combination of burning, grazing, high temperatures and precipitation will have the greatest impact on the water balance and carbon storage, mainly in the paramo, grazing, high temperatures and precipitation can cause accelerated degradation of soils and influence hydrological regulation. based on the Holdridge life zones to identify the spatial distribution of Colombia's vegetation cover according to the of Colombia's vegetation cover according to climate change scenarios A1 and A2 in the periods 2011-2040 and 2070-2011. 2011-2040 y 2070-2011. With respect to high mountain formations (snow and moorlands), they predict that for the scenarios and periods studied that for the scenarios and periods studied, these formations will disappear completely.

From According to Vargas [7], during the period of the El Niño phenomenon, drought periods will be accentuated and periods of drought will be accentuated and prolonged on the dry slopes of the paramo, where more drastic temperatures will occur. Temperatures will be more drastic, which will produce water shortages, changes in fire frequencies and stronger frosts and more severe frosts. On the other hand, on the humid slopes, rainfall will be more intense and frequent, which will be more intense and frequent, causing flooding and soil instability.

## 3. THEORETICAL FRAMEWORK

Fractal theory was constructed at the end of the 19th century and beginning of the 20th century from the contributions of great scientists such as Cantor [8], Sierpinski [9], Hausdorff [10], among others, who contributed notably to reveal the concept of dimension and to the birth of this tool. Henri Poincare initiated the formal study of dynamical systems in the 19th century, laying the foundations for the origin of fractal theory. Mandelbrot [11] introduced the term fractal (from the Latin "fractus") to identify the family of shapes described by this geometry. By means of mathematical different geometric shapes with ideal fractal structure can be generated by mathematical algorithms [11], [12].

Fractal geometry aims to get closer to the shapes, objects and phenomena of nature in mathematical analysis, geometry and topology. Self-similarity and the dimension are two fundamental concepts in its study. Self-similarity is a property that refers to the essential characteristic that the whole is formed by several copies of itself, reduced and placed itself, reduced and placed in different positions, i.e., the whole is equal to its parts, except for a scale factor. The extraneous dimension refers, in the self-similar set, to the fact that the Hausdorff dimension (defines the fractional dimension for a fractal object) is strictly greater than the topological dimension [13].

The details of a fractal at a certain scale are similar, not necessarily identical to those of structures visible at a larger or smaller scale structures visible at a larger or smaller scale. A fractal consists of geometric fragments of variable orientation and size (similar in appearance). It is confirmed that they are statistically equal, that is, if some characteristic is measured, the average value and the standard deviation are equal.

This internal property of resembling each other at different magnifications is called self-similarity. Because a fractal is composed of increasingly finer similar structures, its length depends on the magnification and resolution of the measuring instrument, then, as the resolution of the measuring instrument increases, the length of a fractal also increases the resolution of the measuring instrument increases, the length of a fractal also increases.

The fractal dimension is the number used to quantify how much space a fractal fills, this dimension is determined with values that are not necessarily integers. Therefore, the theories of nonlinear dynamical theories of nonlinear dynamical systems, chaos and fractals, have refuted the validity of scientific or Laplacian determinism. Fractal theory invalidates the claim of predictability of classical systems by introducing complex dynamics classical systems by introducing complex dynamics. Classical Euclidean geometry is no longer suitable for the adequate for the analysis of both mathematical and natural fractal objects [11],[13].

A time series is a set of observations on values taken by a (quantitative) variable at different points in time. The data can behave in different ways over time, in which a trend or a cycle is identified, or it can present an indefinite or random form. A time series can be constituted only by deterministic or stochastic events or a combination of both, some present nonlinear dynamic behaviors whose complexity makes it impossible to formulate a mathematical model based on physical laws that represent their evolution adequately, considering the presence of atypical observations and structural changes

for which there are no mathematical models that allow their representation in the nonlinear case. The traditional analysis of time series is done by decomposing them into several parts; a time series can be decomposed into three components that are not directly observable and only estimates can be obtained: the trend, defined non-formally as the change of the mean over an extended period, represents the predominant behavior of the series.

Seasonality is a periodic movement that occurs over a short and known period. The random component is unpredictable, it represents all types of movement in a time series that are neither trend nor seasonal variations nor cyclical fluctuations, they are erratic movements that do not follow a fixed pattern erratic movements that do not follow a specific pattern and obey diverse curves [12], Mandelbrot [11], explained the behavior of scale-invariant long-term correlations and introduced the fractal model of time series. These models can be applied to population dynamics and in the prediction of species extinction. An important characteristic of fractal models is that their increments are stationary, i.e., independent of time, meaning that a subsequence of a fractal time series has the same fractal exponent as the original series (Hastings & Sugihara, 1993). This is, related to the concept of self-affinity, a form of invariance with respect to changes in time scale [11], [12]. Because time series are structures that can be represented as a function of a single value of a single independent variable and this structure can refer to a varying quantity that fluctuates over time, time series can exhibit fractal characteristics in the form of statistical or exact self-similarity. "Exact and statistical self-similarity describe structures whose precise details or statistical properties repeat as their two dimensions orthogonal dimensions change in size by independent amounts. Because of the incommensurability of the orthogonal axes defining a time-series trace, such structures cannot exhibit self-similarity, only exhibit self-similarity, only self-affinity". When a subset of the data is rescaled appropriately, the resulting plot shares appropriately, the resulting plot shares the general statistical properties of the original trace; therefore, it exhibits original, thus exhibiting statistical self-affinity [12].

The theory of fractal time series models allows for the long-term assessment of the temperature and precipitation as the main variables in determining climate change determination of climate change. The climate system exhibits a long-term memory, the memory plays an important role in climate prediction. This divergent time scale is reflected in this divergent time scale is reflected in the long-term time series which exhibits properties on the scale of the autocorrelation function [14].

A chaotic system is not necessarily random. In many of the time series of time measured in Nature, a range of scales behave in a self-similar manner. For example, the variations that occur in daily and annual temperature, both of which are a cycle, with very similar characteristics, as opposed to very similar characteristics, unlike the scale at which they occur. "Measurements in the self-regulating transients of temperature, pressure, humidity in microclimates" or "even rainfall, which is so seemingly random, also exhibit a self-similar behavior that becomes behavior that becomes evident when studying them in the frequency domain, since they show a structured noise zone, prior to structured noise zone, prior to the white noise frequencies, which corresponds to a self-affine fractal type" (Paredes, 1995).

## 4. METHODOLOGY

Chingaza National Natural Park is located in the Eastern Cordillera of Colombia, northeast of Bogotá D.C., between 4º51' - 4º20' north latitude and 73º30'- 73º55' west longitude, between 4º51' - 4º20' north latitude and 73º30'- 73º55' west longitude, in the jurisdiction of the municipalities of Fómeque, Choachí, Gachalá, Medina, La Calera, Guasca and Junín in the department of Cundinamarca, and Restrepo, San Juanito, Cumaral and El Calvario in the department of Meta (Colombia)

In the great South American Andean System, the Colombian Eastern Cordillera belongs to the Andean-Atlantic Subsystem [15], whose most important characteristic is the humidity it receives from the Atlantic Ocean, the Orinoco and Amazon, which is transported and transformed into orographic precipitation. The Chingaza National Natural Park, one of the most important reserves in the Andean Province, is located within this subsystem of humid springs and is one of the unique ecosystems in the northern tropical Andes: the Paramo [1], [15].

It has an area of 76,600 Ha, but in current cartographic terms and according to the Geographic Information Systems and Radio communications Group GSIR of National Parks of Colombia, the current shape has an area of 78,294 ha. It has altitudes ranging from 800 to 4,020 meters above sea level. Its current area is the result of the efforts of several entities committed to the preservation and expansion of the park since its creation in 1977.

The area protected by the National Park System, Chingaza, is surrounded by four Protected Forest Reserves (RFP): the Blanco and Negro Rivers RFP (to the west), the Chorreras and Concepción Rivers RFP (to the northeast), La Bolsa RFP (to the northeast) and the Sucio River RFP (in the central east), which total nearly 18,000 hectares dedicated to the conservation of high Andean Forest relicts. The rivers that originate in the latter three reserves provide water to the aqueducts of the towns located downstream and are also used to generate electricity for the Guavio system Carpanta Biological Reserve borders the park. It is in the central part of the park, south of the Chuza reservoir, between 2,340 m. and 3,340 m. altitude. It includes mainly Andean Forest, as well as a very small paramuna strip in its upper part [1].

The paramos of Chingaza (NP) are more humid, precipitation describes a monomodal - bistational behavior because of orogenic discharges. The annual average rainfall is 1964.68 mm, and the monthly average is 163.73 mm. Rainfall in Chingaza is high, with peak rainfall between May and August (about 60% of the annual total). The months from December to February are the least rainy months (between 9% and 17% per year) [1]

Temperatures are characterized by low temperatures: minimum temperatures range between 6.7ºand 7.9ºC and average temperatures between 12º and 14ºC, with values below 0ºC throughout the year. The distribution between temperature and precipitation is antagonistic. In the high mountain areas, there is a high cloud cover because of the ascent of large air masses that have warmed in the lower parts [1].

Winds generally present speeds of 2 to 6 m/s. The dominant local winds are from the northwest and from the Guatiquía canyon, which cause the waters to swell in the afternoon. Relative humidity values exceed 80% throughout the year (85% and 90%). In contrast, evaporation is low, with the highest values occurring during the summer between December and February [1].

Cloud cover has a strong influence on luminosity and the amount of radiant energy reaching the Earth, especially during the rainy months. The most radiant months are from November to February and the cloudiest from June to July. Solar radiation is highest in the morning and at night the cooling of the ground causes water condensation. Insolation varies from 2.5 to 3.5 hours of sunshine per day. The maximum value occurs in January (4.2 h/day) and the minimum in July (1.2 h/day) [1].

For the collection of the information, the following was carried out:

a) Identification of information corresponding to the baseline of the study area: climatology, meteorology, vegetation (flora), bioclimate, geology, geomorphology, landscape, life zones and biogeography. Review of climate change, hydrology, vegetation cover, geology and geomorphology maps. Referencing of satellite images of the Geographic Institute Agustín Codazzi. - IGAC.

b) Mapping of information (databases).

c) Comparison and relation of the studies on the mathematical models to study the climate and the Investigations on climatic change carried out in the Chingaza National Natural Park.

d) Compilation of climatic information from Chingaza NNP stations (1970- 2020), mapping and triangulation of the climatic stations of the Natural Park.

e) Statistical analysis of the precipitation and temperature series of the study area.

f) Identification, categorization, research and analysis of fractal and computational mathematical models that allow the development of the model in question to infer climate trends according to the non-linear behavior of the time series of the variables to be studied: precipitation and temperature.

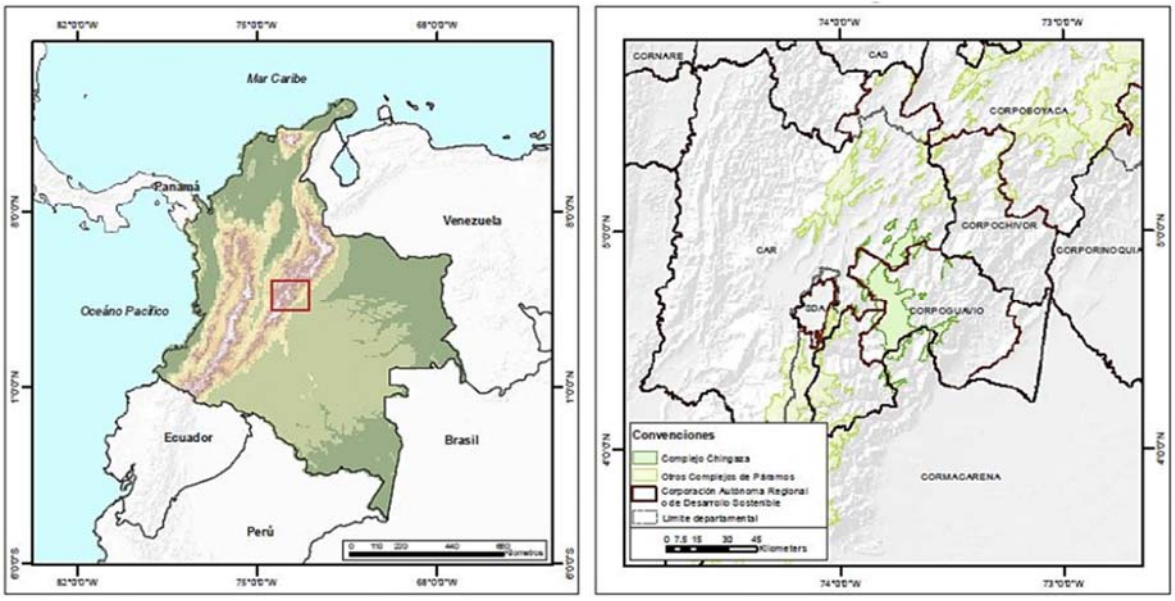


**Figure-2.** General Location Map: Chingaza Paramo Complex. Source [3].

## 5. RESULTS AND DISCUSSIONS

The data processing of the 60 selected studies, which was elaborated in IBM SPSS Statistics 19, the most used methods in climate modeling and prediction are Statistical Models (EM: 87.5%) and General Circulation Models (GCM: 51.79%). Strictly Numerical Models (algorithms) (MN) and Simulation Models (MS) were used in 50% of the selected studies. Theoretical Models (TM) were used in 10.71% of the studies and Neural

Network-based Models (NRM) were identified in 8.93% of the papers.

The analysis variables were selected (Table-5) with respect to the results of the literature review (Table-3). According to the frequency of study, Precipitation (P), Temperature (T), Wind (V) and Humidity (H) are the most relevant in the selected studies with percentages of 71.43%, 69.64%, 33.93% and 30.36% respectively.

The Meteorological approach (M) presented the greatest relevance (87.5%). In order of importance, the Hydrological (H), Ecological (E), Geological (G) and biological approaches presented the following percentages of participation in the analysis: 25%, 12.5%, 8.93% and 7.14%.

According to the spatial amplitude where the scientific explorations were carried out, the Regional (R) scale was the most used (60.71%), followed by the Global (G) and Local (L) scale, with percentages of 35.71% and 26.79%. However, the countries or regions in which most research on the subject is carried out are China, North America and Asia.

The Cluster Analysis performed in R V. 4.0.3. Figure-3 shows the relationship of the studies according to the selected variables, which is calculated according to the Euclidean distance. There are four main clusters which group studies with similar characteristics. For example, the papers by Goerss [16] and Elsner [17] are very similar in terms of the date of the study, the mathematical model used, the climatic characteristics described, the approach and the scale used. The researchers use in the two studies Theoretical Models (MT) to analyze Precipitation (P), Wind (V) and Atmospheric Pressure (PA) with a Meteorological (M) approach at a Regional (R) scale using the Atmosphere-Ocean interrelationship as the unit of analysis. (Elsner & Jagger, 2006) use the North Atlantic Oscillation (NOA) to analyze its influence on Hurricane activity in the United States. On the other hand [16], discusses how to reduce the forecast error in the trajectory of Tropical Cyclones in the Atlantic Basin by means of the Consensus Model derived from the inputs of different models explaining the forecast error through regression models.

In the first phases of the study, no methods, mathematical techniques, or specific studies related to Fractal Theory are identified within the analysis categories. Then the search for fractal models of climate is determined in the different databases.

Characterization of the fractal dimension of the time series of wind speed in different terrain conditions. The authors highlight the importance of fractal analysis in the development of reliable wind speed forecasts, they indicate that the evaluation of persistence in time series is an effective technique in the modeling and forecasting of climate variables such as wind speed.

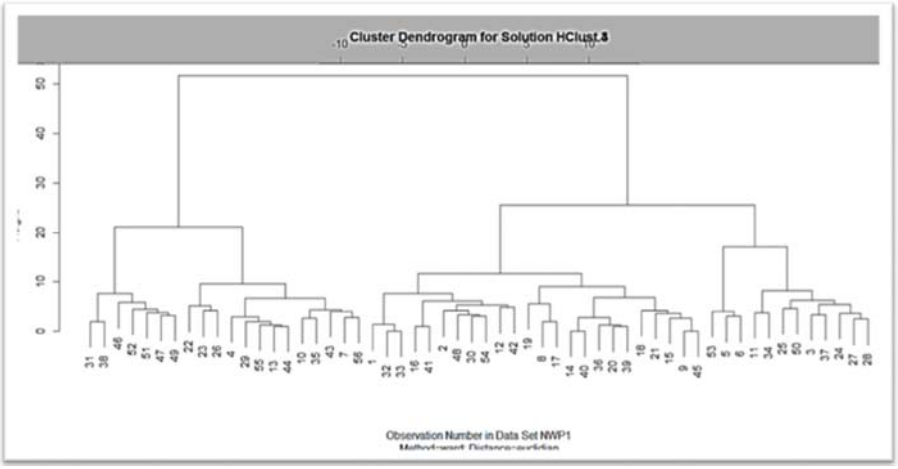


**Figure-3.** Cluster of analyzed research - R.

The climate variables analyzed have the following order of importance: Precipitation (P) (71.43%), Temperature (T) (69.64), Winds (V) (33.93%), Humidity (H) (30.36%), Atmospheric Pressure (PA) (25%), Solar Radiation (17.86%), Vegetation Cover (CV), Evapotranspiration (EVT) (14.29%) and Relative Vorticity (7.14%).

The approach that was most evident in the analyzed papers is Meteorological (M) (87.5%). Hydrological (H), 12.5% Ecological, 8.93% Geological (G) and 7.14% Biological approaches were used in 25% of the papers. The most used scale of work is Regional (R) (60.71%), then Global (G) and Local (L) which are identified in 35.71% and 26.79% of the articles respectively. Studies conducted at the Globe level stood out in the sample, 16 of them performed this analysis (28.57%). The countries or regions with the most research on the subject are China, North America and Asia**.**

For the trend analysis of the precipitation and temperature series, we used time series information on precipitation and temperature from 52 weather stations located in these municipalities (Figure-4). Temperature time series from 52 stations with climatological information located in these municipalities were used in the homogenization and standardization process (Figure-

4). The R x64 4.0.3 software was used to process the climatological data provided by IDEAM [18].

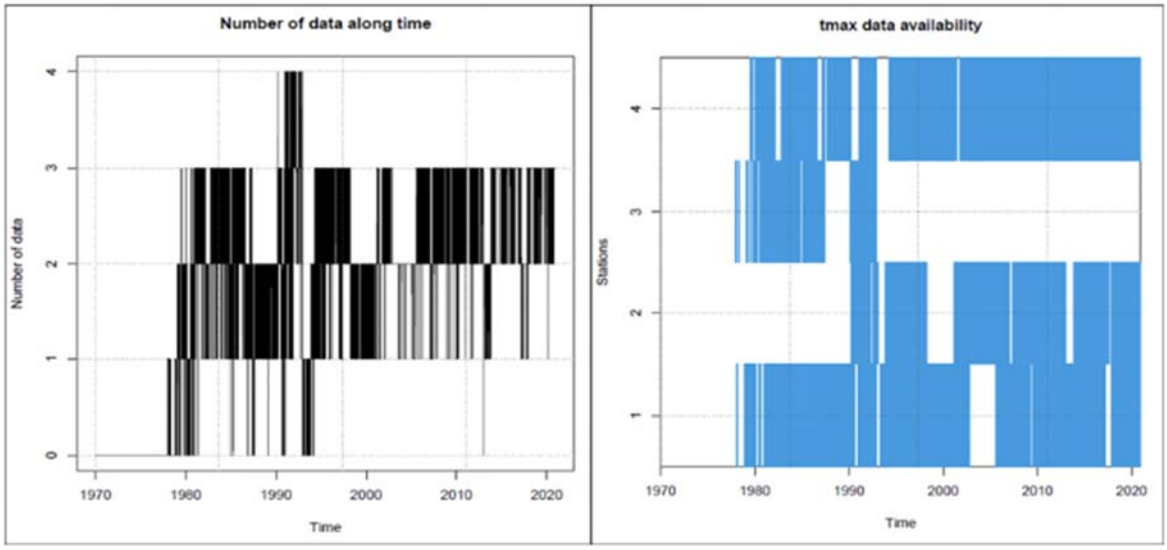


**Figure-4.** Availability of historical temperature data in Chingaza NP during the period 1970 - 2020 - R.

Regarding the availability of daily precipitation data (Figure-5), forty-three stations have representative precipitation data. The period from 1980 to 2011 concentrates the largest amount of available data. Figure-5 identifies the data availability by station and the global data availability. During the study period, all stations have no data available.

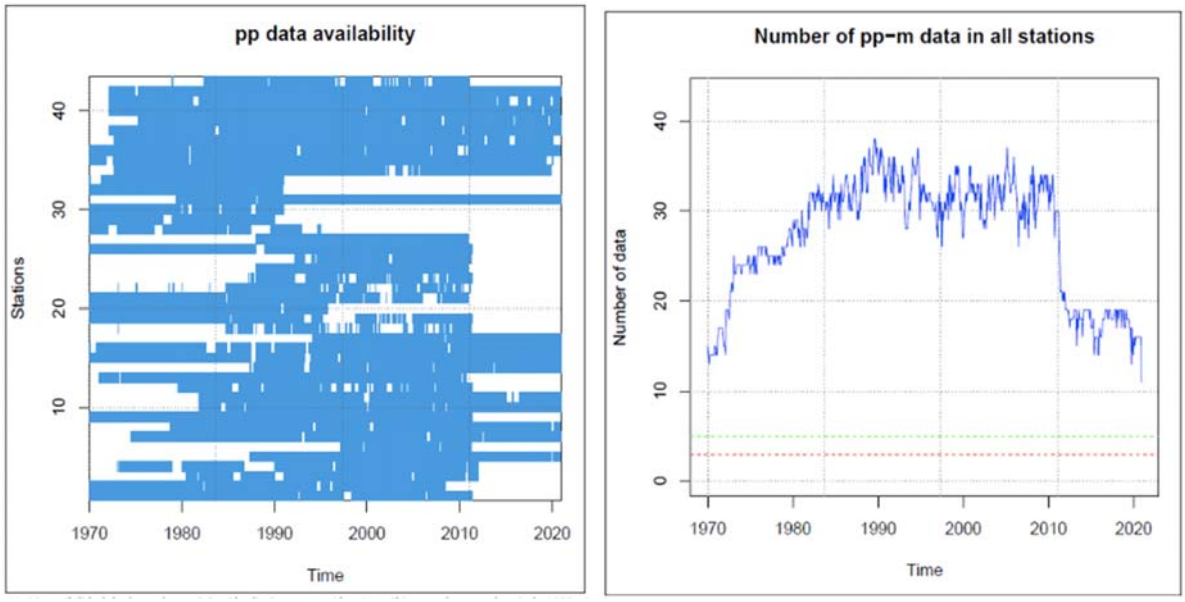


**Figure-5.** Availability of daily precipitation data by station and global accumulated monthly precipitation data- PNN Chingaza during the period 1970 - 2020 - R.

The formulation of public policy has pursued the search for the welfare and improvement of the conditions of the population, through enormous efforts by governments. Food security has been in the framework of public policy concern worldwide in our country, in the constitutional charter is considered as a fundamental right but had not been traced with a clear policy structured with programs, projects and goals that allow the operationalization of the policy and is supported by regulatory legal instruments that allow its operation.

It is uncommon that once the policy is instrumentalized, evaluative and follow-up processes are carried out to account for the effectiveness and efficiency intended with the policies and the instruments derived

from it; the sensations that the beneficiaries of the policy feel, see and are affected by can be perceived through adequate instruments and give a framework not only altruistic of its scope but also of its implementation.

This research proposes a methodology that combines different methods that from the qualitative research allows to register those feelings of the actors involved in the public policy of food security of the capital district, finding as valuable results for those who are responsible for the implementation and operationalization of the policy as well as for the actors who benefit from it, concluding that the applied methodology provides elements of judgment of great interest for the Capital District.

Similarly, from an integrated analysis of the beneficiaries, the policy formulator evidences the ruptures in the information channels by the three groups under study, the search for immediate results and not in accordance with what is formulated in the policy in a race against the presentation of goals or tangible results without taking into account that the operation of the policy is based on a cultural change which is only reflected in the imaginary of the inhabitants and in the long term.

Although the different dimensions of development have been involved both in the formulation and its instrumentation and operationalization, it is clear and according to the results found that they do not have a harmonious dynamic, but on the contrary, unbalanced as shown by the analysis of the Vester Matrix and in which it is necessary to take improvement measures to balance these differences, mainly between the socio-cultural, environmental and economic aspects, which is where the tangible actions that have been taken to the territory have been most concentrated.[8]

Local development, and in turn rural development, will only be achieved when in the minds of the inhabitants small transformations are made that give way to great changes according to the realities of the territory, for the case at hand we sought to identify those agents of change that have enhanced the different components of development and which were analyzed through five factors: improvement in the quality of life, tendency to cultural change, degree of access to the Master Plan services, level of commitment of those involved in its implementation and progress in the implementation process; which register mostly antagonistic perceptions by the three study groups with which the research was carried out.

## 6. CONCLUSIONS

This work performed an analysis of Fractal models worldwide over a period of 17 years (2004-2020) to identify the use of these methods and their categories. A period of 50 years (1970-2020) was established with the purpose of homogenizing, standardizing and processing missing data from the temperature and precipitation series of 54 IDEAM stations in influence of Chingaza NP and, based on this, evaluate the availability of data for the study. Based on the results obtained in section 2, the study period is delimited to 30 years because it is observed that in this period of time the available stations in the park have the largest number of uninterrupted data to perform the climatic characterization of the study area. The Multifractal Model of Fluctuation without Tendency (MFDFA) is developed and evaluated and the daily precipitation time series are described using the Multifractal approach.

The main categories are numerical, statistical, general circulation, theoretical, simulation and neural network models. According to the analysis performed, statistical models (EM) (87.5%) and General Circulation Models (GCM) (51.79%) are the most used methods for weather predictions. Strictly numerical models (algorithms) and simulation models were used in 50% of the selected studies.

In the study of climate from Fractal Theory such as the paper by (Yan *et al.*, 2020) who evaluate the persistence of wind speed time series in Hong Kong through fractal dimension stating that fractal analysis is an important tool in the development of climate models and predictions.

The standardized anomaly values were identified between the range of -6 and 7 and the index of SNHT1 = 30 and SNHT2 = 50, with a maximum standard deviation of 2, this process allowed to obtain the complete, homogenized and standardized data series during the study period. Precipitation trends (Rainfall Day - Daily Frequency) range between 0.00 mm and 100 mm and Temperature (Maximum and Minimum - Daily Frequency) present values between -4a C and 38.2aC in the reference period. The stations with the most

The stations with the most unique data are San Rafael, Las Palomas and La Cabaña and those with the least similarity are La Primavera, Salinas de Upin, Simaya, San José and Fómeque.

The homogenization process with R identifies four complete temperature time series for the temperature analysis and 43 for the precipitation analysis, of which 30 stations comply with a minimum of 30 years of uninterrupted precipitation and a maximum value of 30-34% of missing data, therefore, these series are used in the processing of the fractal analysis because they have the quality and quantity conditions required for this process.

According to the diagram of the behavior of the daily precipitation time series of the study stations, it is inferred that there is a relationship coefficient which homogenizes the variations between the series of the stations evaluated.

A long-term persistent behavior is identified in the precipitation series according to the Trendless Fluctuation Analysis. The preliminary values of WTMM and Wavelet Leader are - 0.82 and -1.45 respectively. The estimated slope is -0.27.

Precipitation in Chingaza presents a Multifractal behavior with long-term persistence, all values of the Hurts exponent in the study stations exceeded the threshold of 0.5.

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